Suppression of heavy ion $\gamma\gamma$ production of the Higgs particle by Coulomb dissociation

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The predicted two-photon Higgs production with heavy ions at the CERN LHC is shown to be reduced due to the large Coulomb dissociation cross section. Incorporating the effect of dissociation reduces the production of a 100 GeV Higgs boson by about a factor of three compared to rates in the literature calculated without this effect. [S0556-2821(98)01901-8]

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The possible production of the Higgs particle or other heavy particles via the coherent two-photon mechanism from colliding heavy ion beams at the CERN Large Hadron Collider LHC has been a subject of much interest in recent years [1–8]. However, with the exception of one recent work [9], the modification of production rates due to Coulomb dissociation of the nucleus has been ignored. Henken, Trautmann, and Baur [9] calculated the effective $\gamma\gamma$ luminosity in conjunction with giant dipole excitation of one of the nuclei and found this higher order process appreciable when compared to the $\gamma\gamma$ luminosity calculated without consideration of other processes. In this paper we investigate the effective suppression of Higgs production at LHC due to interference of Coulomb dissociation not only via the giant dipole state but also through equivalent photons of up to many GeV impinging on each nucleus in its rest frame [10]. The large magnitude of these higher excitations is seen in the recent calculated cross sections for Coulomb dissociation in Pb+Pb collisions at LHC: including all excitations led to 220 barns; including only the giant dipole excitation led to 127 barns [10].

In the standard calculation the two colliding heavy ions (e.g. Pb+Pb) are assumed to travel on straight line trajectories at an impact parameter such that their densities do not overlap. Each of the ions produce a spectrum (equivalent photon number) of Weizsacker-Williams photons of energy ω dependent on the transverse distance b_i

$$N(\omega,b_i)=\frac{Z^2\alpha\omega^2}{\pi^2\gamma^2}\,K_1^2\left(\frac{b_i\omega}{\gamma}\right) \tag{1}$$

where K_1 is the modified Bessel function and γ is the relativistic factor of the colliding ions seen in the center of mass frame. The effective $\gamma\gamma$ luminosity function at a given equivalent mass W is then given by [4,5]

$$L_{\gamma\gamma}(W)=2\pi\int\frac{d\omega_1}{\omega_1}\int_{R_1}^{\infty}b_1db_1\int_{R_2}^{\infty}b_2db_2 \times\int_0^{2\pi}d\phi N_1(\omega_1,b_1)N_2\left(\frac{W^2}{4\omega_1},b_2\right)\theta(b-R_1-R_2) \tag{2}$$

where R_1 and R_2 are the nuclear radii and b is the ion-ion impact parameter

$$b^2=b_1^2+b_2^2-2b_1b_2\cos(\phi). \tag{3}$$

The θ function excludes impact parameters where densities overlap. The cross section for producing a particle in the heavy ion collision is then

$$\sigma(W)=\frac{8\pi^2}{W^3}\,\Gamma_{H\to\gamma\gamma}(W)L_{\gamma\gamma}(W) \tag{4}$$

where $\Gamma_{H\to\gamma\gamma}(W)$ is the two photon decay width of the Higgs boson.

From Fig. 2 of Ref. [10] one can see that the probability of a colliding Pb ion being dissociated in the field of the other Pb ion at LHC is approximately equal to $(1-\exp[-(17.4/b)^2])$ where b, the impact parameter, is in fermis. The survival probability (neither ion being Coulomb dissociated) is then approximately $\exp[-2(17.4/b)^2]$. A parallel calculation including only the giant dipole resonance gives a corresponding survival probability of approximately $\exp[-2(11.2/b)^2]$.

Figure 1 shows the effect of Coulomb dissociation on the luminosity function for the $\gamma=3000$ of LHC. R_1 and R_2 were set at 7 fm. The upper curve is the luminosity without dissociation, the middle curve shows the luminosity reduced by Coulomb dissociation via the giant dipole resonance, and the lower curve includes Coulomb dissociation to all final states.

We now calculate Higgs production at LHC. Calculation of the width $\Gamma_{H\to\gamma\gamma}(W)$ is a textbook exercise [11–13]. The mechanism is dominated by triangle loops of which the $W^{\pm}$ is most dominant followed by the top quark. Lower mass contributions are relatively insignificant and we have ignored them here. Figure 2 shows the effect of Coulomb dissociation on Higgs production. The cusp at 160 GeV is at twice the mass of the $W^{\pm}$. At 100 GeV the production rate of the Higgs boson is reduced by more than a factor of three from the rate calculated without Coulomb dissociation. Note that the effective suppression factor depends on the kind of detector used to select the $\gamma\gamma$ mechanism. If one uses the lack of activity in the zero angle calorimeter the suppression fac-

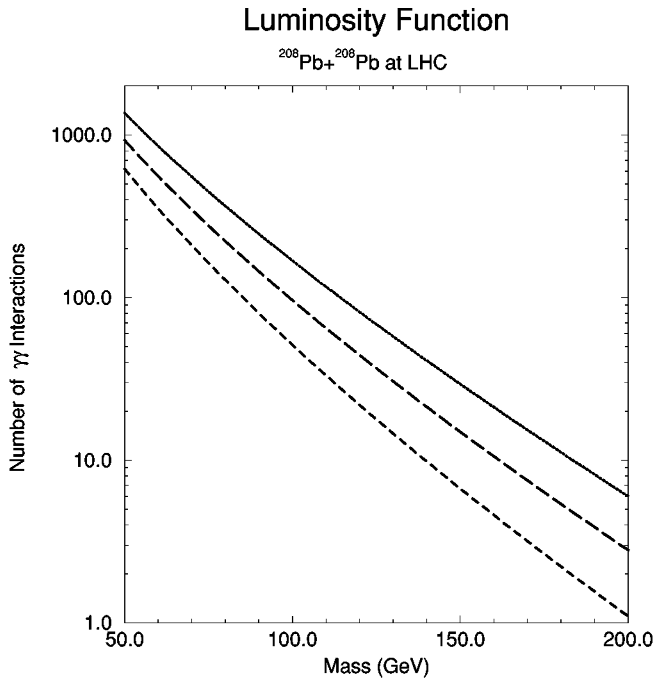

FIG. 1. $\gamma\gamma$ luminosity function. The upper curve is without dissociation, the middle curve includes Coulomb dissociation only via the giant dipole resonance, and the lower curve includes Coulomb dissociation to all final states.

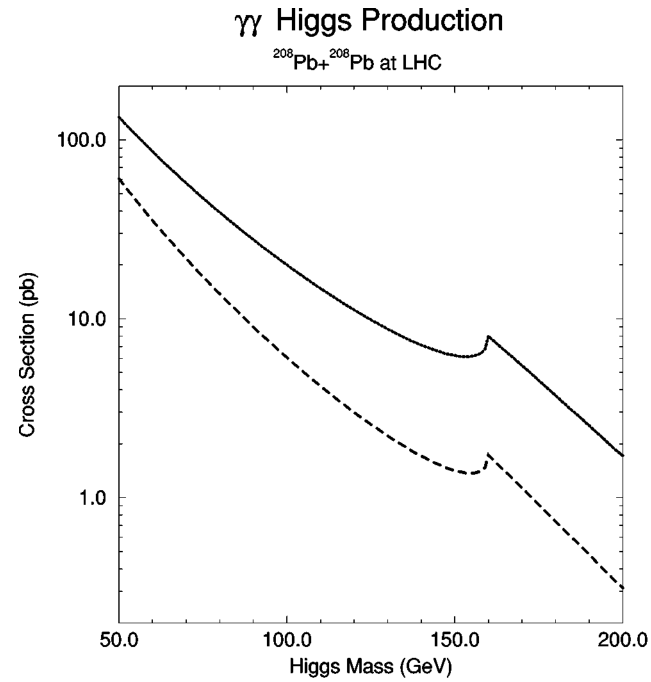

FIG. 2. Coherent electromagnetic Higgs production at LHC. The upper curve is without dissociation, and the lower curve includes Coulomb dissociation to all final states.

tor is as we calculated above. On the other hand if one uses a detector with a wide rapidity coverage such as one discussed for the FELIX detector [14] the Coulomb dissociation would lead to much less of a suppression.

Note also that the calculated rates are fairly sensitive to the radius and impact parameter cutoff. If we set R_1 and R_2 to 8 fm rather than 7, then the 100 GeV Higgs is reduced by 41% on the top curve and by 30% on the bottom curve. Such an increase in radius is maybe justified by a large (~ 2) increase of the radius of the strong interaction at LHC energies [15] as compared to the incident energies ~ 1 GeV which were used to determine the effective nuclear radii for pA interactions.

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